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## WHAT ARE THE BASICS OF CRYSTAL RADIO RECEIVERS?

Here is the schematic diagram for a very basic crystal radio set without any particular embellishments. This basic old time radio uses no power other than that provided by the transmitting antenna from the radio station. Free power from the sky eh!. It truly is a marvel!.

As a matter of interest, some amateurs and experimenters living in the vicinity of high powered AM Radio transmitters have literally used crystal radio sets to trickle charge their batteries. Now THAT is real COOL! If the demand exists we will do it too!.

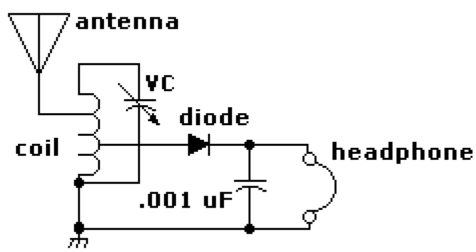


**Figure 1 - schematic of a basic crystal radio set**

**NOTE:** For people unfamiliar with metric measurements used here 25.4 mm equals 1"

This circuit consists of an **inductor** (also called a coil), a **variable capacitor** (used to be called a variable condenser), a germanium **diode** (formerly called a crystal), a filtering capacitor and finally very high impedance headphones.

The inductor has taps on it:

(a) one to connect the antenna to.
(b) one lower down to connect the detector diode to.

**These taps are often best determined by experimentation**

The variable capacitor is usually connected across the whole of the inductor to form a **tuned circuit** for our crystal radio set.

**Note:** the bottom junction of the inductor and variable capacitor is connected to ground / earth - **literally**.

### Earth connection for crystal radio set

For the crystal radio set circuit to perform at all well you will need a very good earth connection. A length of old steel water pipe driven **deep** into damp earth is ideal. The electrical earth or

water service at home is **NOT** a good or safe earth for this project, in fact it is **VERY DANGEROUS**. - see **earth dangers**.

The funny looking symbol connected to the top of the inductor or coil and variable capacitor denotes an antenna. The higher and longer (50' or 17 metres) this antenna is, the better the likely reception. Reality says of course you can erect an antenna in the space available with the material available. Consider running the antenna around the top of your fence line if is not metallic.

### Safety comes first with our crystal radio set

KEEP WELL AWAY FROM POWER LINES AND POWER SOURCES - **REPEAT AFTER ME** - I PROMISE TO KEEP WELL AWAY FROM POWER LINES AND POWER SOURCES.

Always remember the motto "safety first in everything". At this site here I stress that all the time - "safety first" and I can never stress it enough. See my important page about **earth dangers**

### Antenna for crystal radio set

Remember we're using the antenna (aerial) to get free power here and we want to capture as much as possible from the sky for our crystal radio set.

Perhaps you might like to review some **antenna basics** before proceeding.

**Technical Note:** Radio signals (waves) such as we encounter in the am radio band have two halves. One half travels across the surface of the earth at the speed of light through people, buildings and other objects. The other half, a mirror image, travels beneath the surface of the earth. This radio wave has a definite length. Its length is the speed of light divided by the frequency. For frequencies in the megahertz region this approximates to 300 divided by the frequency in megahertz. These radio waves we want to detect with our crystal radio set

An example which we use later is the **am radio band** of 530 Khz to 1650 Khz. These frequencies when converted to .53 Mhz and 1.65 Mhz respectively give wavelengths of 566 metres and 182 metres.

Now some critical aspects:

**Variable Capacitor:** Here you should try and salvage one from an old time radio. Just make sure the radio is not in the "vintage" class and now worth hundreds of dollars. The ideal ones are nearly impossible to buy now. Unless you have access to measuring equipment you will have to guess the capacitance. A lot of old time radios had capacitors which tuned about 15 pF to 365 pF.

**Inductor or Coil:** Here we are normally dealing with an air cored inductor wound on some suitable **non metallic** form. Some examples are - cardboard toilet roll former, a short length of PVC tubing 40 mm, 50 mm, 90 mm or 100 mm diameter.

**Diode:** In lieu of the old crystal detector we use a germaniumdiode of the 1N34 or OA90 type. Do NOT use a 1N914 type.

**Fixed Capacitor:** This is for filtering and may be .001 uF, 1 NF or 1000 pF type (all those values are the same - just expressed in different units). Something near in the same values is quite O.K.

**Headphones:** This is by far the hardest part to obtain. The type used for hi-fi **WILL NOT** work here. Ideally you need high impedance 2,000 ohm types but these are nearly impossible to find. You can sometimes buy 1,000 ohm crystal earpieces (no **not** the usual transistor radio type). The headphone is a high impedance load for the crystal set and as we are working on free power from the air we can't load it down. If you used the 8 ohm hi-fi type it would be like trying to run your electric toaster off a very small battery. The power is not available. Remember we're using free power from the sky.

Further reading on **Headsets for Crystal Radios** by Alan R. Klase.

**Frequency range:** The frequency range of a set like this is mainly determined by the square root of the *ratio of Maximum Capacitance to Minimum Capacitance of the variable capacitor.* In the example above this would be the square root of 365 divided by 15 or about 4.9:1. In the real world there are other capacitance's in the circuit that you can't see (called "strays") and they affect the minimum value. In practice I would expect a real range of about 3:1

**A.M. Radio band:** Depending upon your country this would cover about 530 Khz to about 1650 Khz. This is slightly more than a 3:1 ratio.

Let us assume for discussion our capacitor was as described above. And for convenience we have strays of about 25 pF (typical). If we add this to both the Max and Min capacitance we get 390 pF Max and 40 pF Min - a ratio of 9.75 the square root of which is 3.122. Happily this also happens to be nearly the ratio of Freq $_{max}$ divided by Freq $_{min}$ or 1650 Khz / 530 Khz. How about that?

Of course these variable capacitors were deliberately manufactured that way for that very reason!

Well now we have to resonate our capacitor with the inductor. What inductance do we need?. The easiest formula is this - take the frequency in Megahertz (i.e. freq in Khz divided by 1000) and square it. Using our two frequencies 530 Khz and 1650 Khz we would have to square both .530 Mhz and 1.65 Mhz which of course become 0.2809 and 2.7225

And you thought maths at school was/is a waste of time!.

These two figures are divided into the standard figure of 25330.3 respectively. The 530 Khz one (0.2809) would give us LC 90175 and the 1650 Khz one (2.7225) will give us LC 9304. Now when tuning a crystal set the more capacitance you use (plates meshed further in) the lower the frequency you receive. In our case we are using a max of 365 pF + 25 pF strays or 390 pF total. At our lowest freq of 530 Khz the LC (L means inductance and C means capacitance) is 90175 and when divided by our C of 390 pF we get a needed inductance of 231.2 uH (uH means micro henry, a unit of inductance).

Similarly if we go to the highest frequency of 1650 Khz our required LC is 9304 and when divided by our minimum capacitance's (reduce the capacitance by withdrawing plates from one another and go higher in frequency) of 15 pF + 25 pF strays or 40 pF we get a required inductance of _______ uH?. Go on work it out. And remember we are only interested in whole numbers because we have made a number of approximations here.

Now how do we get a needed inductance of about **230 uH?**.

Gee whizz not more maths headed our way!

The formula for inductance - using toilet rolls, PVC pipe etc. can be well approximated by:

$$\text{Inductance } L = \frac{0.394 * r^2 * N^2}{(9 * r) + (10 * Len)}$$

**Here:**

r = radius of the coil i.e. form diameter (in cm.) divided by 2
Len = length of the coil - again in cm.
L = inductance in uH.
* = multiply by

Now assume we have used a piece of PVC pipe of about 104 mm (10.4 cm) diameter. This has a radius of 5.2 cm. Let us wind a coil consisting of 57 turns (with taps at about every 5 turns) over a length of 104 mm or 10.4 cm. For the Mum's and Dad's who work in old measurements that's 4". This is a piece of standard 4" PVC sewer tube.

**Politely** ask any plumber on any building site for a scrap off-cut about 150 mm (6") long. In another life I'm also a plumber and we like to help polite people.

Let's put those numbers into the our formula above and do some sums:

0.394 * 5.2 * 5.2 * 57 * 57 = 34614

**AND** ( 9 * 5.2 ) + ( 10 * 10.4) = 46.8 + 104 = 150.8

**AND** 34614 divided by 150.8 = about 230 uH

Boy am I a clever kid or what. Did you work through that on paper all by yourself? I do hope so.

Why and how taps every 5 turns?. The why first - in the beginning I said connections from the antenna (aerial for old timers) and diode would need to be experimented with. With taps you can select different spots along the inductor.

How?. Easy! Wind your inductor as follows:

You will need a length of enamelled copper winding wire (about 24 gauge or 0.5 mm dia) about 20 metres long - yes you will need just about all of it. You will also need some matches (used are O.K.). Assuming you have a 150 mm piece of sewer tube or similar, drill a small hole approx 25 mm (1") from one end. Drill a similar hole 104 mm further away toward the opposite end (or even 20 mm in from the opposite end). Basically the idea is for the holes to be nearly 10.4 cm apart. or *the length of the coil you are winding*.

Push through about 15 cm (150 mm) of wire and wind the short end through a couple of times to form an anchor (knot) at that point. Then holding the wire tightly wind 5 complete turns spaced about three wire diameters apart from each other (you really need a helper here). Under the 5th turn slip a very short length of match, continue winding very tightly placing a match piece under every 5th turn until you have wound 57 complete turns. Tie a knot similar to the other end and again leave about 150 mm left over. **CAREFULLY** with a sharp knife scrape the enamel insulation away on all 5th turns as well as about 5 mm from the end of the two end pieces.

Presto! there you have a 57 turn inductor of about 230 uH with accessible taps at about every 5th turn.

**How it works:** (simple version)

Well we have the antenna. This picks up the radio signals from the sky and with our real good earth we hopefully get lots and lots of signals.

The inductor combined with different settings of the variable capacitor selects the frequency you want to listen to and discards all others.

This selected signal goes through the germanium diode and is rectified. This means we are left with the audio frequencies a human being can hear (music - words). This audio has been stripped off the radio signal by the diode. The small .001 uF capacitor gets rid of any of the radio signal left. We can then listen to these very tiny audio signals through our headphones or crystal earpiece.

**How it works:** (complicated version)

Your long wire antenna and earth wire will pick up thousands and thousands of radio signals from the air. The exact setting of your variable capacitor will determine a set amount of capacitance and this in conjunction with the fixed inductance of your coil we have a **resonant circuit**.

As an example, in my locality we have a very strong AM station at 630 Khz. Using the formula above for **resonant frequency** we find the LC combination (inductance times capacitance) required to receive this signal is:

$25330.3 / (0.63)^2 = 63820$

Therefore if we had a fixed inductance of 230 uH then our variable capacitor (including strays) would need to be set at the point where it exhibits 63820 / 230 **OR** 277 pF. In other words a capacitance of 277 pF in conjunction with an inductance of 230 uH resonates at 630 Khz. We can rather generalise here and say, although not strictly accurate, that this coil / capacitor combination will **ACCEPT** only signals at 630 Khz and **REJECT** all others. This is the way we select our particular frequency from among the thousands and thousands of other signals on our antenna.

Our signal at 630 Khz has been "modulated" at the radio station with audio frequencies (speech and music). Because it is **A**mplitude **M**odulated it is called **A.M.**

This means the original 630 Khz signal strength (amplitude) at the transmitter is expanded and contracted by the audio frequencies.

After being selected by our coil / capacitor combination the 630 Khz signal is passed to the germanium diode. As the signal passes through the diode only one half of the signal is used and the fixed .001 uF capacitor dumps the 630 Khz signal to ground leaving a very tiny audio frequency which is an exact replica of the audio frequencies (speech and music) as they originated in the radio station's studio.

This very tiny audio signal then drives our crystal earpiece or high impedance headphone so we can hear the words and music. If it were amplified many, many times over it would then have the power to drive a loudspeaker. The speaker cone goes in and out at the same audio rate as the original 630 Khz signal is modulated. The moving loudspeaker cone creates a tiny sound pressure level in the room to which your ear is able to respond.

### Radio Kits for Beginners and Youngsters of ALL Ages!

My special amateur radio friend Bruce Kizerian, KK7ZZ who has worked tirelessly for years helping the young and not so young get effortlessly into radio now has a site devoted to "Radio Kits for Beginners and Youngsters of ALL Ages!".

There has been a crying need for these kits and Bruce now fills that need.

Check out Bruce's **"Radio Kits for Beginners and Youngsters of ALL Ages!"**

### NEW! - "High Sensitivity Crystal Set"

Build a "crystal radio " by using a new zero-voltage-threshold MOSFET. By Bob Culter, N7FKI as printed in QST [Amateur Radio Magazine] January 2007

Check out the PDF file of the whole article - **"http://www.arrl.org/files/file/Technology/tis/info/pdf/culter.pdf"** 467 kB. **PS:** The article can be more than somewhat highly technical for newcomers though.

**NEXT:**

Put it all together and reload this page by typing in the URL - www.electronics-tutorials.com/receivers/crystal-radio-set.htm and **tell me how your crystal set works** for you.

If you are real keen you can also check out the **crystal set society's** home page.

Another excellent article (in pdf format) is from the ARRL. From QST December, 1997 **The Crystal Radio**

### Fox Hole Radio

Another VERY interesting project is the **Fox Hole Radio**. Building a foxhole radio is rewarding and the basic setup is very simple. It is, however, difficult to adjust, and it may take several

attempts to find a proper razor blade for the detector. This is a project that requires patience and much trial and error, but it will pay off once it begins to work. It will help to be versed in the construction and operation of crystal sets before building one. These sets are extremely simple in construction, but tuning and modification require some basic understanding of theory, as well as practice. All sets presented here are based on old articles, notes, and people's recollections. There are fairly major variations in design and materials among these plans. It must be remembered that these were improvised under often adverse conditions; there was no "standard" design. With this in mind, take this entire article as a whole, and use it a bit here, a bit there, to build towards a Fox Hole Radio design that works best using modern materials.
See: **Fox Hole Radio**

### A Candle powered Radio

Yep a World Book Science Project from a looooonnnng time ago.
See: **Candle powered Radio**

### A BOOK I THOROUGHLY RECOMMEND FOR YOUNG PEOPLE

**Radio Rescue**
by Lynne Barasch


**From Booklist**
Gr. 2-5. In 1923, a 10-year-old New Yorker became the youngest licensed amateur wireless radio operator. In a clear, first-person voice, the boy describes what Morse code is, how operators used wireless radios to send and receive signals, and his experiences setting up an in-house transmitting station. The boy finds fame when he picks up a signal from Florida hurricane victims and radios for help, and the story concludes with a reproduced newspaper photograph and the full Morse code alphabet. An introductory note reveals that the story is based on the author's father and gives readers background information on the era's telephones and the alternative that the wireless offered, including examples of how Morse code has been used throughout its history. In a well-designed mix of insets, brief sketches, and full-page drawings, the author's uncluttered color cartoons do an excellent job of illustrating the technology and the code, at the same time creating likable, expressive characters. Tehnology-minded children may see parallels between the freedom and excitement of the wireless and the Internet in this engaging read. *Gillian Engberg Copyright © American Library Association. All rights reserved*

**ORDER - U.S.A. - Radio Rescue now!**

**ORDER - Canada - Radio Rescue**

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### ANOTHER EXCELLENT SCIENCE FAIR PUBLICATION

**Janice Vancleave's Guide to More of the Best Science Fair Projects** by Janice Pratt Vancleave - 160 pages

This book by Janice Vancleave I can recommend to concerned parents and proves a very inexpensive source of the "Best Science Fair Projects". This book aims to help children to have fun and get winning results as well. Advice is given about choosing, developing and displaying a winning project, along with dozens of science fair experiments.

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The absolute fastest way to get your question answered and yes, I **DO** read most posts.

This is a mutual help group with a very professional air about it. I've learn't things. It is an excellent learning resource for lurkers as well as active contributors.

### RELATED TOPICS on crystal radio set

Check out Bruce's **"Radio Kits for Beginners and Youngsters of ALL Ages!"**

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**capacitance**

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